A Dual-Branch Convolutional Neural Network with Gated Recurrent Units Network for Enhanced Multimodal Stress Monitoring from Wearable Physiological Signals

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Objectives

- ❑ Design a **lightweight** deep learning model for stress detection.
- ❑ Optimize for real-time inference on wearable devices.
- ❑ Use **raw BVP and EDA** signals as direct input.
- ❑ Avoid **hand-crafted** features to ensure simplicity and generalizability.

Materials and Methods

Dataset

- ❑ Utilized the publicly available **WESAD** (Wearable Stress and Affect Detection) dataset **[1].**
- ❑ Includes BVP and EDA signals sampled at **64 Hz and 4 Hz respectively** from **15 subjects**.

Signal Preprocessing

- ❑ **30s** non-overlapping segments.
- ❑ **Normalization** (zero mean, unit variance).
- ❑ Sliding window-based **minority class augmentation**.

Deep Learning Model

- ❑ Implements a dual-path architecture.
- ❑ Contains only **.43M parameters (1.64 MB)**.

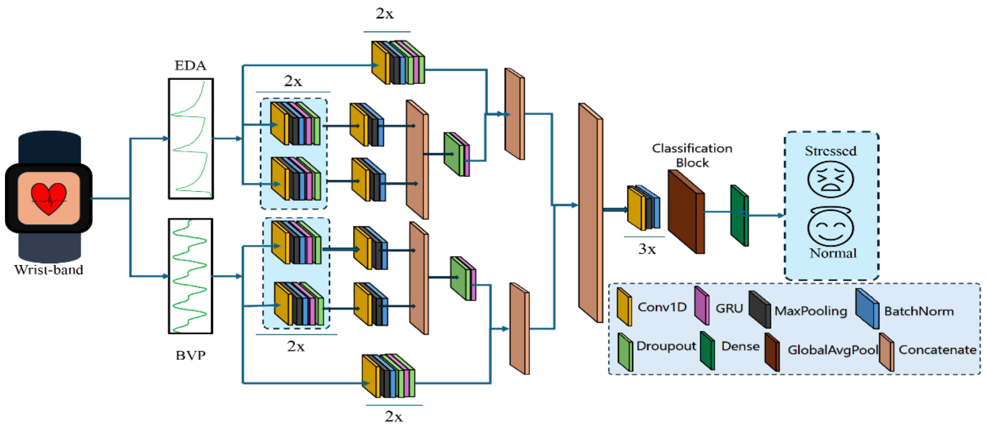

Figure 1: Architecture of the proposed lightweight deep learning model for stress monitoring.

Results

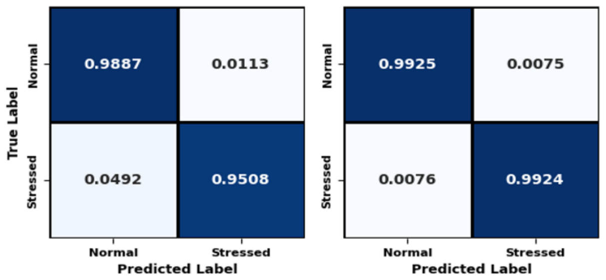

Figure 2: Normalized confusion matrices of the LOSO cross validation without (left) and with augmentation (right).

Results (Contd')

Table I: The performance scores using LOSO cross-validation, with and without augmentation, are reported for accuracy, F1 score, specificity, sensitivity, AUC, and Cohen's kappa (k) in (%).

Aug	Acc	Spe	Sen	F1	AUC	k
No	97.53	98.87	95.08	96.14	98.47	94.34
Yes	99.27	99.25	99.29	99.97	99.68	98.40

- ❑ Strong validation performance was achieved.
- ❑ Data augmentation significantly enhanced the results.

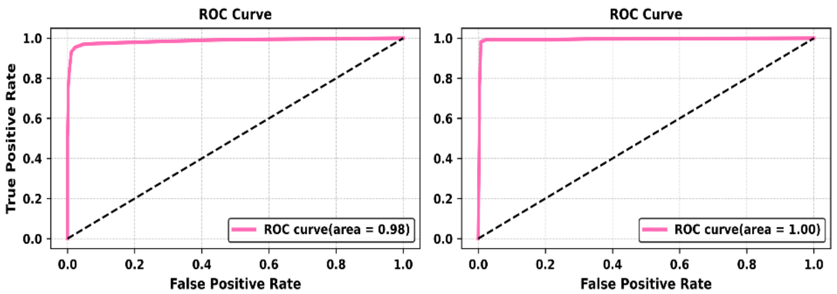

Figure 3:ROC curves showing AUC values of 0.98 for without augmentation (left) and 0.99 for with augmentation(right), highlighting the model's robust performance.

Discussion

Table II: Ablation study results showing the performance of individual signals (EDA and BVP) instress classification. Accuracy (Acc), specificity (Spe), sensitivity (Sen), F1-score (F1), AUC, andCohen's κ are reported in percentages (%).

Signal	Acc	Spe	Sen	F1	AUC	k
BVP	97.37	98.11	96.21	96.01	98.93	94.05
EDA	93.55	94.34	92.05	90.47	95.95	85.61
BVP + EDA	99.27	99.25	99.29	99.97	99.68	98.40

- ❑ Multimodal BVP+EDA delivers the best overall results, surpassing single-signal models.

Table III: Comparison with existing literature.

Study	Dataset	Signal	Accuracy
[2]	WESAD	BVP, EDA,ACC, TEMP	87.12
[3]	WESAD	EDA, EEG,PPG	87.40
[4]	WESAD	PPG	94.90
This Work	WESAD	EDA, BVP	99.27

- ❑ Our method achieves the highest accuracy compared to existing studies.

Conclusions

- ❑ Lightweight CNN-GRU model using BVP signals.
- ❑ Achieves 99.27% accuracy and strong overall performance.
- ❑ Promising for continuous, non-invasive stress monitoring.
- ❑ Future work on multi-class classification and deployment on resource constrained devices.

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